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Research supervised by : J.S. de Vries

Research carried out by : A.N. de Jong

ABSTRACT (ONGERUBRICEERD)

False alarms and missed detections are common problems to any autonomous surveillance system. The present investigation describes the possible causes for the occurrences of false alarms and missed detection in a demonstration system based on an electro-optical sensor for the autonomous detection of wildfires. After an analysis of the basic physical principles of autonomous wildfire detection, the possible causes for false alarms / missed detections are investigated. Based on the false alarm / missed detection analysis the design of an autonomous wildfire detection sensor is described.

This work has been carried out in a project (nr. 0040) in the framework of the EPOCH programme of Directorate-General XII of the Commission of the European Communities in Brussels, and for Bosschap in The Hague.

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Onderzoek uitgevoerd o.l.v. : dr. J.S. de Vries

Onderzoek uitgevoerd door : ir. A.N. de Jong

SAMENVATTING (ONGERUBRICEERD)

Valse alarmen en gemiste detekties zijn normale problemen bij ieder geautomatiseerd bewakings systeem. Het onderzoek dat in dit rapport wordt gepresenteerd, beschrijft de mogelijke oorzaken van valse alarmen en gemiste opsporingen bij een demonstratiesysteem dat is gebaseerd op een electro-optische sensor voor de automatische opsporing van branden in bos- en natuurgebieden. Na een analyse van de fundamentele natuurkundige principes van de geautomatiseerde opsporing van bosbranden worden de mogelijke oorzaken van valse alarmen en gemiste opsporingen onderzocht. Gebaseerd op de analyse van valse alarmen en gemiste detecties wordt het ontwerp voor een geautomatiseerde sensor voor de vroege opsporing van natuurbranden kort beschreven.

Dit werk is uitgevoerd in een project (nummer 0040) in het kader van het EPOCH programma van het Directoraat-Generaal XII van de Commissie van de Europese Gemeenschappen in Brussel, en het Bosschap in 's-Gravenhage.

CONTENTS

INTRODUCTION

The purpose of forest fire surveillance and detection is to minimise the time between the onset of fires and the fire suppression in order to minimise damage and hazards. In order to optimise the capabilities of forest fire surveillance systems, a careful, physical analysis of the forest fire problem is required: The basic problem is to reliably detect forest fires as early as possible using affordable surveillance systems. Beginning forest fires are embedded in a natural environment and are observed by electro-optical sensors from ground based platforms, aeroplanes or satellites through an intervening atmosphere.

In this progress report an outline will be given of the physical aspects related to forest fire detection, such as the physical characteristics of the atmosphere, the natural environment in which forest fires occur, the forest fire itself, and a description of the electro-optical sensor, which has been designed for forest fire surveillance and detection using the physical description of the environment. After the general introduction and discussion on the physical aspects of forest fire observability, the discussion will concentrate on the particular aspects and trade-offs made for autonomous surveillance systems using a ground based network of sensors, and the various false alarms which may be expected. The last chapter will discuss in detail the methods which will be applied to minimise the number of false alarms.

1 FOREST FIRE DETECTION PRINCIPLES

A good understanding of the physical aspects of electro-optical surveillance of wildfires is required to be able to maximise the detection efficiency of a sensor designed to detect wildfires shortly after onset. Therefore, this chapter will describe the physical aspects related to forest fire detection and surveillance. The chapter begins with a general description of the radiation transfer in the atmosphere and wildfire smoke clouds, followed by a discussion on the colour and contrasts of forest fires embedded in a natural environment.

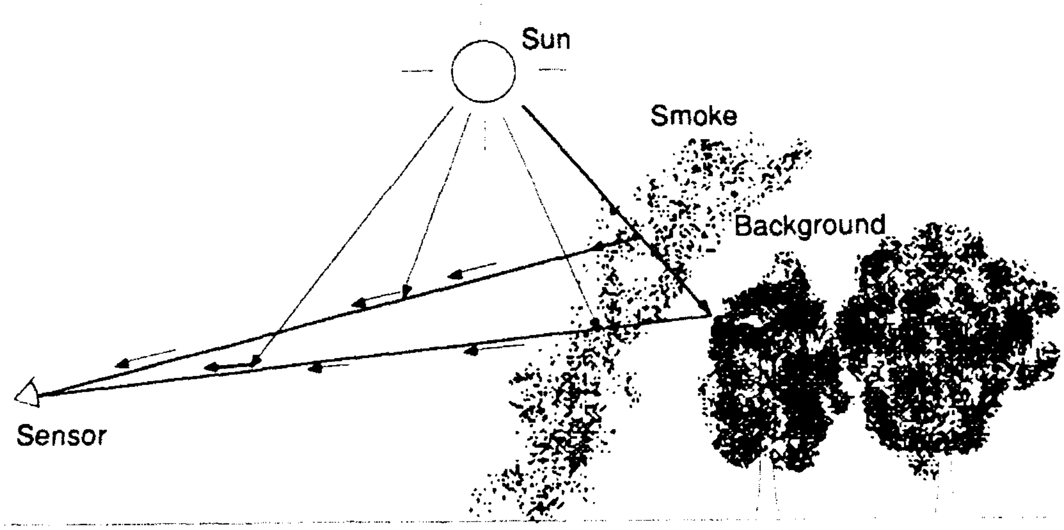

Figure 1. Schematic presentation of the problem of forest fire detection. The solar radiation (visible), which is scattered and partly absorbed by the atmosphere, illuminates the forest fire and the background in which the fire is embedded. The background and forest fire scatters and absorbs the solar irradiation. Then, the sensor detects the scattered radiation of the background and the fire, which is, on its way to the sensor, again modified by atmospheric extinction and solar radiation scattered into the line of sight.

1.1 Radiative transfer in the atmosphere

Along the path of the solar radiation toward the sensor, the atmosphere strongly influences the observability of forest fires by absorbing and scattering radiation from and into the line of sight (LOS). The basics of the interaction of the solar radiation with the earth atmosphere, the forest fire and the sensor is schematically depicted in Figure 1. The atmospheric influence on solar radiation is wavelength dependent as is easily proven by the observation that a clear sky is blue and the sun becomes red at sunrise and sunset when to path length of the solar radiation through the atmosphere increases. In the visible wavelength band all the detected radiation are ultimately photons emitted by the sun and which are scattered by objects and atmosphere towards the sensor. The propagation of radiation through the atmosphere is governed by the radiative transfer equation. In general, the solution of the radiative transfer equation for a scattering and absorbing atmosphere involves complex mathematical techniques which, except for very special and often less important cases, will not yield closed-form solutions. Compromises in the establishment of the boundary conditions or approximations are made to effect a mathematical formulation amenable to reasonably handy solutions. Principle among these is the assumption of single scattering.

The extinction of radiation which traverses a medium is proportional to the initial radiance, to the density of the attenuating medium, and to the distance traversed, ds, so that

$$dL_\lambda(\lambda,s) = -k(\lambda,s)\, L_\lambda(\lambda,s)\, \rho\, ds \qquad (1)$$

where $L_\lambda(\lambda,s)$ = spectral radiance at a point s with co-ordinates (x,y,z) in $W\,cm^{-2}\,sr^{-1}\,\mu m^{-1}$

ρ = density of the medium ($g\,cm^{-3}$)

$k(\lambda,s)$ = spectral mass extinction coefficient ($cm^2\,g^{-1}$)

= $k_a(\lambda,s) + k_S(\lambda,s)$

$k_a(\lambda,s)$ = spectral mass absorption coefficient

$k_S(\lambda,s)$ = spectral mass scattering coefficient

In what follows, the effects of the atmosphere on the observability of forest fires and its environment will not be derived mathematically, however, the resulting effects will be discussed and explained in some detail. Further reading on this subject can be found in Reference 2.

1.1.1 Atmospheric propagation

All along its propagation through the atmosphere the solar radiation is partially scattered and absorbed, before and after being scattering by the background. The combined effect of absorption and scattering is often referred to as 'extinction'. The extinction is the result of the interaction of radiation with air molecules and aerosols. Hence, since the solar spectrum is known, the effects of the atmospheric influence on the solar radiation at the location of the object - which will scatter and absorb it - can be determined. The observational consequences of the atmospheric influence on radiation (i.e. absorbed background radiation and solar radiation scattered into the line of sight) is a decreasing contrast between a forest fire and its background when the distance to the forest fire increases, since the effects of the absorption and scattering of solar radiation into the LOS are proportional to distance. This influence strongly depends on the weather, in particular on the humidity and the concentration of aerosols in the atmosphere.

The atmospheric influence is strongly wavelength dependent (Figure 2) and can be attributed to two different mechanisms, molecular and continuous extinction. The visible wavelength range is found from 0.35 - 0.7 μm. As can be seen in Figure 2, there is no molecular absorption in this band. However, at longer wavelength bands the molecular absorption increases in some particular wavelength bands. Most of these absorption are due to water molecules, however, some particular bands are due to carbon-dioxide.

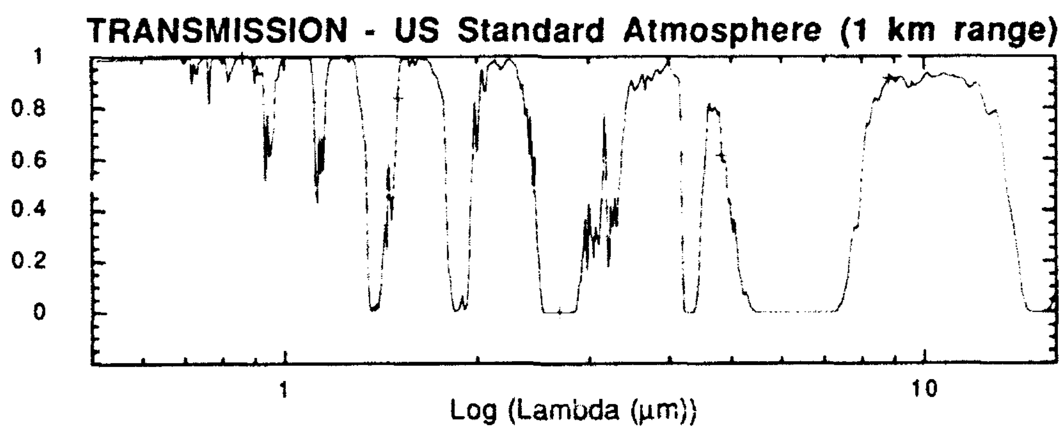

Figure 2. Transmission of the atmosphere as calculated with the atmospheric model Lowtran 7 for a standard atmosphere and a range of 1 km. The calculations were carried out excluding continuous extinction by molecules and aerosols.

The first wavelength dependent extinction mechanism results from the selective absorption of particular molecules in the atmosphere, such as carbon dioxide, carbon monoxide, water vapour, etc. The absorption of photons at particular wavelengths ('lines', often present in groups, called 'bands') are caused by vibration-rotation transitions induced by the photon absorption in the molecules (Figure 2), while photons at other wavelengths are re-emitted.
The second wavelength dependent extinction mechanism is caused by aerosols and gaseous molecules in the atmosphere and are responsible for the continuous extinction (see Figure 3). Three kinds of continuous extinction can be distinguished, (i) Rayleigh scattering, (ii) aerosol extinction and (iii) continuous molecular extinction. The last contribution is only important at infrared wavelengths.

The first contribution is the Rayleigh scattering of radiation on air molecules in the visible wavelength ranges at 0.35 - 0.7 μm. The Rayleigh scattering has a strong wavelength dependence and increases strongly toward the shortest wavelength. Rayleigh scattering is responsible for presenting us a blue sky on sunny days.

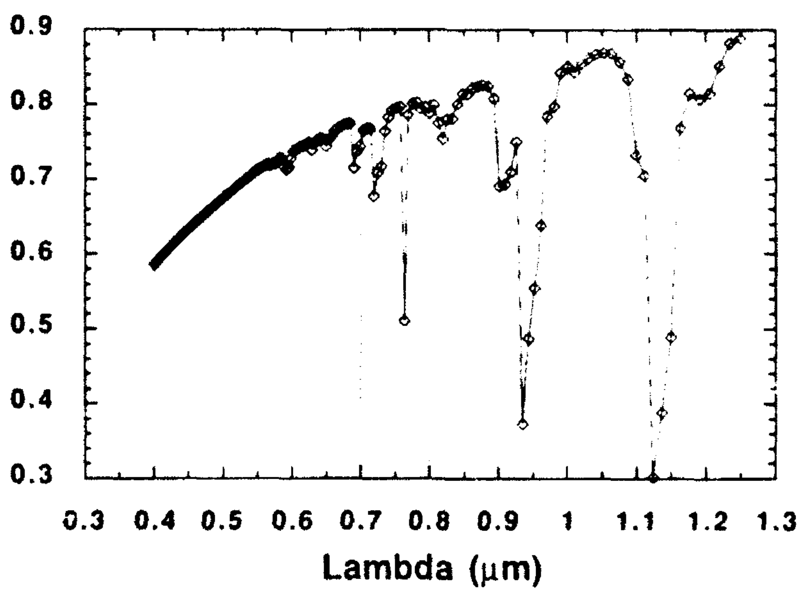

Figure 3. Transmission of the atmosphere in thevisible wavelength range, including molecular absorption and continuous extinction by aerosols over a range of 1 km. The transmission spectrum was calculated using the Lowtran 7 model for a standard atmosphere for a range of 1 km and visibility of 23 km. The effect of greater ranges is that the total transmission decreases.

The second contribution to the continuous extinction is caused by aerosols. Aerosols are small particles with sizes of the order of 1 μm which are (i) naturally produced, such as by vegetation, sand and dust storms, volcano's and smoke, and (ii) by human industrial activity. Extinction by aerosols depends on the concentration of aerosols in the air, the size distribution of aerosols and their scattering properties, which depend on both wavelength, angle and shape of the particle. Usually, the scattering properties of aerosols are calculated using the Mie scattering theory for spherical particles. While the assumption of sphericity is valid for liquid aerosols, it is generally not for dust particles. However, there is no practical method for exact calculation of scattering by non-spherical particles. A detailed description of the scattering properties can be found in many textbooks on this subject . Also here, Reference 2 gives an excellent overview on the subject.

1.2 The background

The electro-optical surface properties of the elements or objects in the background, including the forest fire itself determine the absorption and scattering (a/o. reflection) of visible and near-infrared (solar) radiation. Important physical parameters of the elements in the background for forest fire surveillance and detection are the electro-optical properties of the soil, vegetation, the fire and the smoke. The most important physical parameters are the angular and the spectral dependencies of the electro-optical surface properties.

In the background artificial objects such as metallic rooftops, cars, houses etc. may strongly reflect sunlight, however also rocks and vegetation at wavelengths below the 'red-edge' at 0.7 μm may show specular reflections. Specular reflections, i.e. of solar radiation, can have an important impact on the surveillance and detection since it may cause false alarms in the detection processing algorithms of autonomous forest fire surveillance systems.

The angular dependence of the scattering properties (Figure 4) can be large: for instance, if the radiation is purely reflected ('specular reflection'), hence no diffuse reflective, or scattering component (i.e. $\phi = 0$) is present, the surface acts as a true mirror. In this case the scattering distribution is a strongly peaked around the angle of reflection. However, if the scattering component ϕ increases and approaches 180°, the scattering becomes uniform, meaning that there is no relation between angle of incidence and of reflection. In general, both the reflective as the scattering components are present on surfaces. To simplify the analysis and modelling of the angular dependent scattering processes the scattering of radiation at surfaces is usually approximated by a pure reflection component (specular reflection) and a pure diffuse, or scattering component. This simplified model is called the bi-directional reflection model (BDRM), which is often applied in calculating computer generated images.

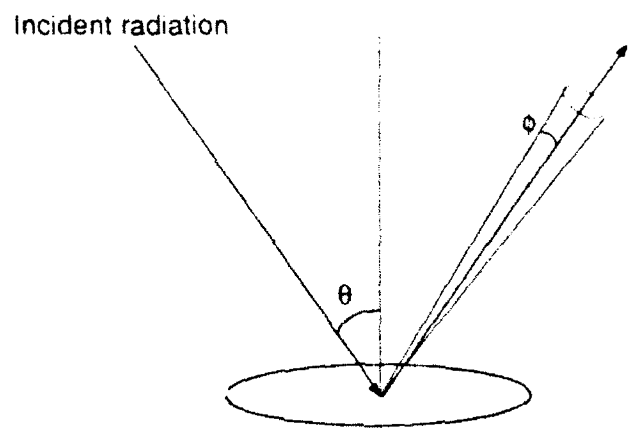

Figure 4. *Bi-directional reflectance model (BRDM): Angular dependence of electro-optical properties.* θ is the angle of incidence and reflection. φ is the amplitude of the diffuse component

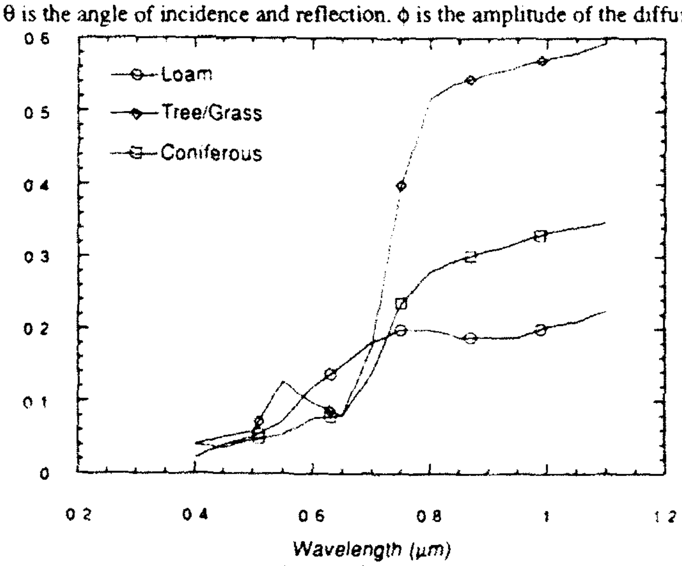

Figure 5. The reflectivity of grass, conifers and loam.

The spectral dependence of reflectivity is of significant importance to autonomous forest fire surveillance, since the spectral characteristics of the forest fires and background elements can be used to enhance the contrast of a forest fire with respect to its background. One of the most important constituents of the background is the vegetation, in which a forest or wild fire occurs by definition. The reflective properties of vegetation and loam, another element in a natural environment, are shown in Figure 5.

The characteristic spectrum of chlorophyll in the visible wavelength range can be used to automatically identify vegetation in acquired imagery, if the surveillance sensor is sensitive in two or more bands on both sides of the red edge at 0.7 μm. Other elements in the background, such as loam (Figure 5), and rocks etc. do not have such a strong wavelength dependent behaviour and behave more like grey bodies, partly scattering and absorbing incident radiation (7).

For ground based surveillance applications the smoke cloud is often also observed against the sky above the horizon. Since the path through the atmosphere just above the horizon is long the observed scattered solar radiation into the line of sight is large. Hence, the sky above the horizon is typically brighter and whiter than in the zenith (Figure 6).

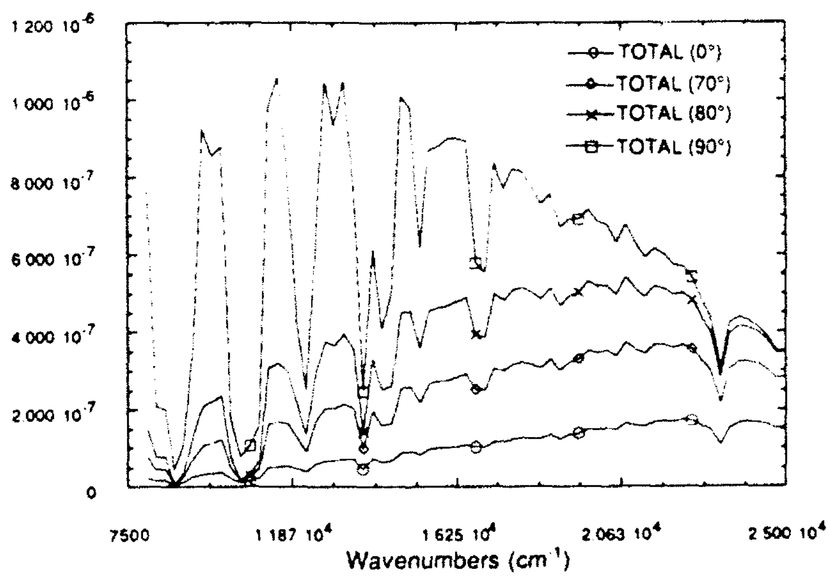

Figure 6. Total sky emission (W cm^{-2} s^{-1}sr^{-1}) as a function of wave number (1/wavelength) for 4 zenith angles (0° corresponds to zenith and 90° at horizon), calculated using Lowtran 7 with multiple scattering.

1.3 Forest Fire

The observability of beginning forest fires is determined by the size of the wildfire. From an observational point of view a forest fire can be separated into two distinct components: the fire and its resulting smoke cloud. The size of a fire and the observability of the smoke cloud is the result of the evolution of the wildfire and is determined by the local circumstances, such as fuels, moisture, wind, slopes, etc., which will be discussed elsewhere.

The visibility of the smoke in the visible wavelength band is in principle determined by the fuels and by the size of the forest fire (Figure 7). The smoke cloud consists of exhaust gases, smoke particles or soot and water vapour. Soot is responsible for the white/blue colour of the smoke cloud of a beginning forest fire.

The amount of water vapour present in a smoke cloud is in part determined by the moisture content of the fuel, and for the other part produced by combustion. As soon as the water vapour in the smoke cloud condenses during the cooling by convection and radiative heat loss, the smoke cloud becomes visually apparent as a white cloud.

If the number of black smoke particles in the smoke cloud increases, which depends on the fuel type (i.e. concentration of resins) and the richness of combustion, then the colour of the cloud will turn darker.

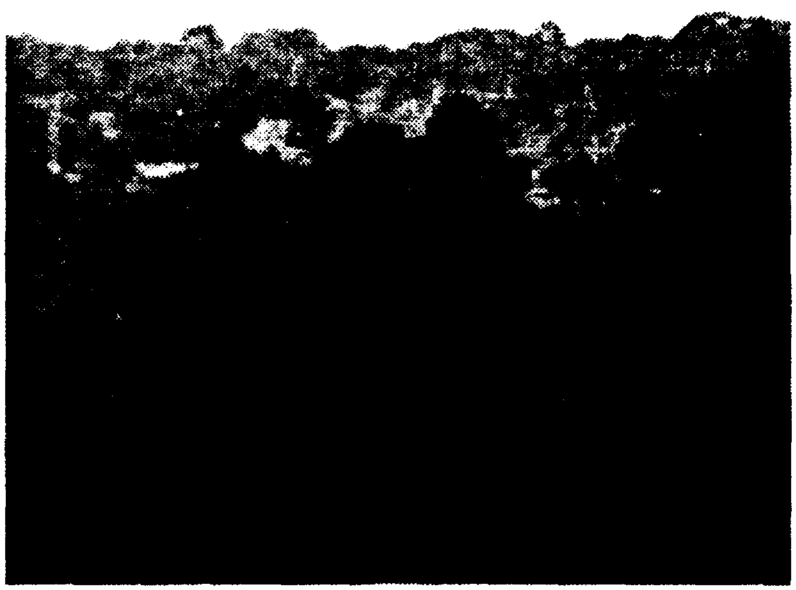

Figure 7. Visible image of a small forest fire during an experiment in 1987 obtained using a red filter. The fire is at a range of 1500 m.

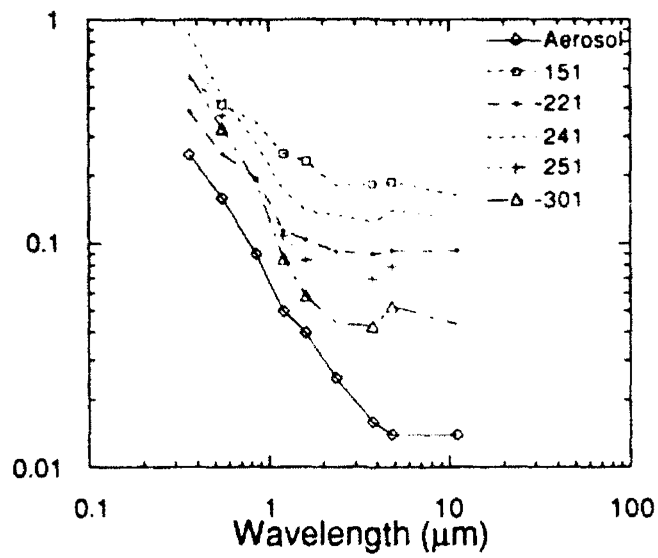

Figure 8. Attenuation of radiation by smoke particles as a function of wavelength, compared to aerosols. Each curve represents a measurement. The number represents the time in seconds since the start of the measurement.

2 THE SENSOR

In this chapter physical aspects of electro-optical sensors are discussed relevant to the surveillance and detection of forest fires in their environment. Parameters such as contrast, signal-to-noise ratio, dynamic range etc. are discussed in such detail, that a good understanding can be obtained of sensor parameters important to sensitive detection of forest fires. These concepts are general to surveillance and detection at both visible and infrared (IR) wavelengths.

2.1 Contrast

The basic problem of forest fire detection using electro-optical sensors is the ability of the sensor to discriminate a forest fire, or for that matter any object, from its background. There are many ways to discriminate a forest fire from its background, i.e. temporal, spatial and spectral discrimination. However, every detection method, a/o. the human perception of the onset of a forest fire as observed by the eye-brain combination, makes first of all use of the temporal variations observed in the radiation received from the background. These temporal changes are usually interpreted as contrast variations, where the contrast refers to an object, defined by the circumference of the change in illumination induced by i.c. a possible forest fire, with respect to its unchanged background. Hence, the contrast of an object is always expressed with respect to another object or i.e. the background. Usually, the definition of contrast is given as (1):

$$C = 0.5*(F_o - F_b) / (F_o+F_b), \qquad (2)$$

where F_o and F_b refer to the measured irradiation from the object and background resp..

2.2 Detector noise

In order to be able to discriminate small contrasts of distant starting forest fires the noise of the detector should be minimised, since it is the noise in the sensor that ultimately determines the minimum detectable contrasts. The fundamental, physical lower limit on the noise is determined by the inherent statistical fluctuations in the distribution of the incoming photons, and not by noise introduced by the electronics behind the detector used to extract the signal. Many other sources of noise are also known to have a significant influence on the performance of photon detectors, such as lattice Generation-Recombination noise, 1/f-noise, Johnson noise, shot noise etc. (2).

Most modern detectors are photon detectors, which absorb photons producing free charge carriers which change an electrical characteristic of the responsive element. In principle each photon generates a free electron ('photo-electrons'). In practice, however, the efficiency of photo-electron generation is lower. Photon detectors for the visible and mid-infrared are produced in one- and two-dimensional (1-D and 2-D) matrices or arrays of detectors. During the integration time - the time detector is active converting photons into electrons - the photo-electrons are accumulated in capacitors or wells, physically located under the photo-detectors. After the integration, the photo-electrons are read-out to be processed by the electronics of the system. The read-out of the photo-electrons gathered by the detector array is usually carried out by a Charge-Coupled Device (CCD). A detailed description of the operation of CCD's can be found in Ref. 2. The CCD read-out is usually an important contributor to the noise generated by detector-arrays, in many cases more important than the photon noise. Therefore, in order to optimise the performance of detector arrays the read-out noise must be minimised. One of the easier ways to lower the read-out noise is to lower the read-out frequency of the array.

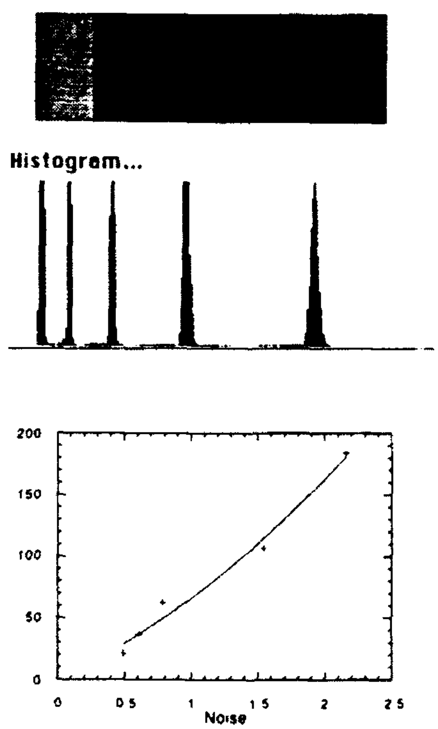

Figure 9. Grey level vs. Noise. Top shows the image of grey level wedge acquired using a '16-bit' dynamic range camera. The middle shows its histogram and the bottom graph depicts the relation of grey level vs. noise. A quadratic curve shows the relation.

2.3 Dynamic Range

In order to optimise the signal-to-noise ratio of CCD's the photo-electron capacity of the wells should be as large as possible. However, in practice the photo-electron capacity is limited.
The maximum number of photo-electrons which can be stored in the wells before read-out is called the saturation level of the detector. The range of the system noise level (usually measured when there is no light incident on the array) up to saturation level is referred to as the dynamic range of the detector array. Many commercial camera's using CCD detector arrays, such as those used for consumer and professional video camera's, have dynamic ranges of 100 - 250 (6 to 8 'bits') because the human eye is not capable of discerning more grey-levels on a screen. Hence, the maximum signal-to-noise ratio for each detector in the array is the square root of the dynamic range, or typically 8 - 16 (Figure 9). Hence, the minimum detectable contrast - which may be defined as the contrast which equals 1σ noise - is already a large fraction of the total dynamic range. The sizes of these CCD arrays are typically 512*512 detectors.
However, most scientific and data processing applications require much higher dynamic ranges. Nowadays, CCD arrays with dynamic ranges of about 10^5 (or almost 17 bit) are commercially available for the visible and mid-IR wavelength ranges. Hence, the signal-to-noise ratio's, if fully illuminated, for these detector arrays are app. 256 (8 bits).
Detector arrays - such as CCD's - with a high dynamic range are capable of discerning much smaller contrast differences than similar arrays with a low dynamic range at the same photon flux levels and are for this reasons better suited to detect beginning forest fires at large ranges, thereby reducing the number of surveillance sensors required to monitor a particular area.

2.4 Spatial resolution

The spatial resolution of a sensor system expresses the capability of the sensor to resolve small angular details. The spatial resolution is determined by the size of an individual detector in the detector array and the focal length of the optics in front of the camera (Figure 10). The angular resolution of a single detector in an detector array is defined as the "Instantaneous Field Of View" (IFOV), and equals to

$$IFOV(rad) = d / F \qquad (3)$$

where d = detector size

F = focal length of the lens

The IFOV is expressed in radians. For example, if the requirement for the spatial resolution of the surveillance sensor is to resolve an object of 1 meter at a distance of 10 km (IFOV = 10^{-4} rad = 0.1 millirad), and the detector size is 20 m, then the focal length F of the lens of the sensor needs to be 200 mm.

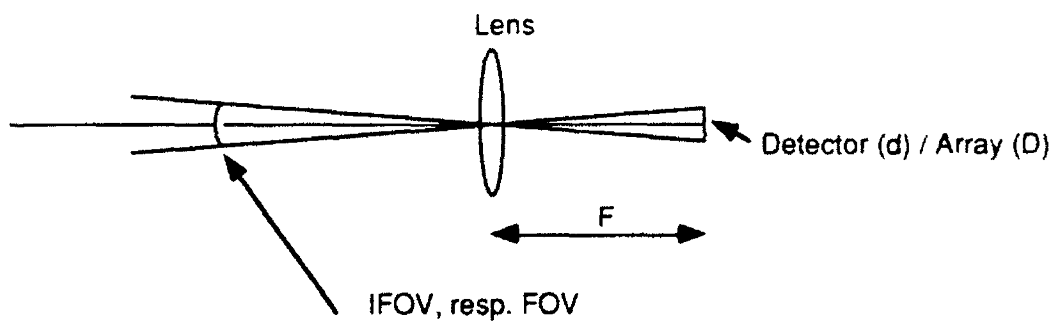

Figure 10. Definitions of instantaneous field of view (IFOV) of a single detector of an array and the field of view (FOV) of the whole array.

The Field of View (FOV) of the sensor is defined by the size of the array and the optics, and is equivalent to the image size expressed in radians (in 1-D):

$$FOV(rad) = D / F \tag{4}$$

where D = n * d = array size

n = number of detectors on 1 axis

2.5 Minimum resolvable contrast

The minimum resolvable contrast that a sensor can discriminate is an essential parameter for any surveillance sensor, because the smaller the change in illumination which can be detected by the sensor - i.e. the earlier a forest fire can be detected - the sooner the suppression of the fire can start, or alternatively, the same fire can be discovered at a greater range at the same time. By minimising the minimum resolvable contrast the cost of any surveillance system may be reduced. The minimum contrast which a sensor is capable to resolve, is determined by (i) the noise characteristics of the sensor, (ii) the dynamic range of the sensor and by (iii) the size of the detected object.

To understand the last point, consider the detection of an extended object (larger than one pixel): If the signals of a group of N pixels belonging to this object are co-added, the measured noise in each pixel of the object reduces with a factor of N (since each detector measures independently from the other), which means an increase in the S/N ratio of the object of N. However, if the same object is at twice the range the area or the number of pixels on the object reduces by a factor 4, and hence the S/N reduces by a factor 2.

3 GRO'JND BASED SURVEILLANCE & DETECTION

Ground based surveillance and detection systems consist of a network of horizon scanning sensors overlooking the top of the trees, such that each sensor has a free look-out over the surrounding area. The operation of ground based autonomous forest fire surveillance and detection system is very similar to the ground based surveillance by humans from look-outs:

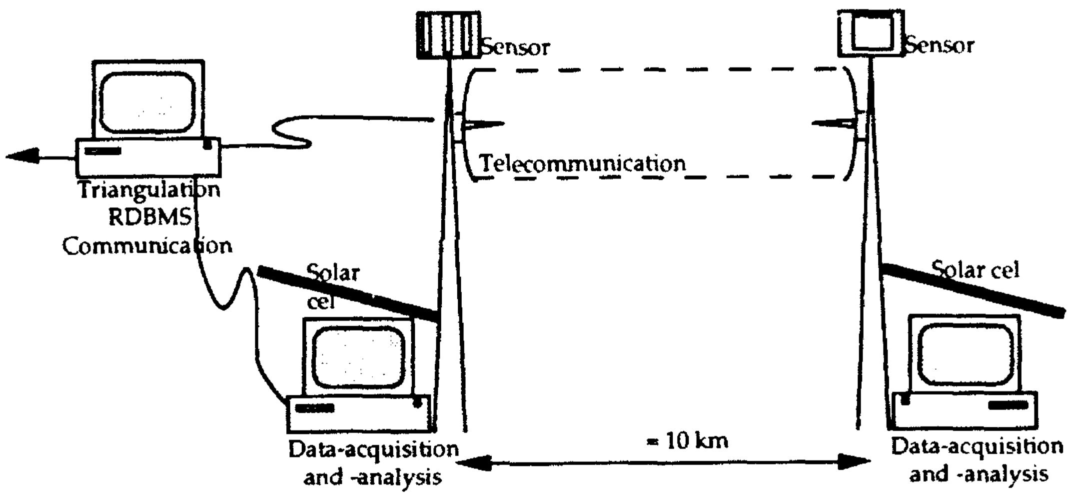

Figure 11. Basic set-up of a ground based autonomous forest fire surveillance system. Each individual sensor in the field (right) is accompanied by an image processing system to analyse the acquired imagery. The directions of derived alarms are relayed to a central co-ordination facility (left), where locations of possible fires are calculated (i.e. by triangulation in flat areas).

The sensor scans the horizon and a few degrees below in case of a flat environment and a larger vertical FOV in case of a mountainous area. If the sensor in combination with the analysing computer near the sensor detects an alarm, it transmits the direction in which the alarm has been detected and other relevant data of the alarm to the central co-ordination facility. Often the central co-ordination facility will have the opportunity to use the sensor to view the direction of the alarm.

In the central co-ordination facility the direction information from other sensors operating in the area for this particular alarm will be combined to derive the co-ordinates of the location of the alarm by triangulation in case of a flat natural area and by GIS information in mountainous areas (since direction directly translates into an accurate location; Figure 11). In order to be able to perform triangulation for every alarm in the area, each location in the area should be monitored by at least two sensors. Therefore, the separation between each sensor should be approximately equal to the detection range of a single sensor.

3.1 Autonomous Detection

The majority of forest fires starts on the ground. Therefore, beginning fires in forested areas will often be hidden by trees, shrubs, etc. to sensors which are overlooking tree crowns and which use slant paths to monitor the area. For this reason, ground based sensors using IR sensitive detectors will not be able to detect ground fires since vegetation is also opaque to the IR emission of the fire. In most cases these small ground fires develop blue/white smoke clouds which will become visible above the trees due to convection as a result of the heat release. Since the smoke clouds are generally not visible in the IR because of their scattering and emission characteristics (Figure 12), detection of smoke clouds should be done at the shortest wavelengths possible, hence in the visible wavelength range.

In order to optimise the detection rate of forest fires the contrast of the blue/white smoke cloud against its environment should be maximised. Therefore, the background should appear as dark as possible with respect to the smoke. Hence, the detection becomes optimal in the minima of the chlorophyll reflectivity spectrum, which are at 400 nm (blue) and 670 nm (red) resp. in the visible wavelength range (Figure 3).

On the other hand, the extinction by the atmosphere increases towards shorter wavelengths as a result of the combined effects of the Mie scattering by aerosols and Rayleigh scattering by air molecules (Figure 5). This means that for a given contrast at a particular wavelength the detection range increases larger toward longer wavelengths (in atmospheric windows). Hence, when considering the atmospheric extinction, the network density of a ground based system, goes down if the detection and surveillance is done at the longest wavelengths possible, and therefore its cost.

Hence, for the arguments given above, the optimum choice of wavelength band for the ground based detection of the blue/white smoke clouds of beginning forest fires in a natural environment is at 670 nm.

When the smoke cloud is dark, i.e. due to the presence of much resin in the fuel, then the detection of the cloud should be done against a white background, which happens to be at wavelengths longer than 700 nm for a background dominated by vegetation (beyond the red-edge, Figure 5). In other cases the smoke cloud can be better observed against the sky background, when the smoke cloud is dark with respect to the sky background. This occurs when (i) the smoke cloud is dark, or (ii) when the smoke is seen in the direction of the sun when the sun is low above the horizon. In the last case, forward scattered solar photons by the atmosphere cause the high sky brightness.

3.2 False Alarms, Missed Detection's...

The simplest form of autonomous detection is carried out by comparing two subsequent images of the same scene using an image processing system: If a difference is found between the two images above a certain threshold which is defined by the noise in the images, an alarm has been detected. However, in a natural environment many of these alarms may turn out to be false and may be the result of

i) variations in illumination by the sun, i.e. due to moving clouds;
ii) variation in atmospheric transmission;
iii) daily motion of the sun;
iv) motions in the image, i.e. trees moving in the wind;
v) human activities, such as cars, people etc.;
vi) birds, other animals;

In order to minimise the false alarm rate (FAR) of the autonomous forest fire detection system, efficient use should be made of the available information present in the image. Additional information, may be provided by weather stations, which provide data on the variations in the solar illumination over time, atmospheric attenuation etc., and by a database providing other information, such as geographical and historical data on the area under surveillance.

In the following the possible origin of false alarms which may occur in the system are described in detail. The chapter will be divided into sections according to the types of alarms listed above that may be discriminated according to the detection techniques. Since minimising the false alarm rate is a key issue in the performance of the autonomous forest fire demonstration system, it also drives the design of the sensor. Hence, after the discussion of the possible causes for false alarms and their reductions, the set-up and implementation of the hard- and software of the sensor will be discussed. As explained in short above, the simplest form of detecting the white smoke of an starting wildfire is based on the comparison of two subsequent images obtained in the red wavelength band, and therefore makes use of temporal information resulting from the changes in landscape which occurred in the time span between the two images. The detection is carried out by taking the modulus of the subtraction of two subsequent digital images. If a systematic difference has been found, which is significant with respect to the detector noise, then an alarm has been found.

If the time interval between the two scans is very short, i.e. in the range of tens of milliseconds (for instance in the case of video recordings), the changes between two sequential images will be small and are mainly the result of noise in the detector. Since the noise will be similar in nature all across the image, these difference are easily automatically identified as noise. However, if the time interval between the two images increases to the order of seconds or minutes, the likelihood of differences other than noise becomes much higher. In a time interval of one minute - which will be the approximate time interval between each scan in the autonomous forest fire detection demonstration system - many variations between the scans may have occurred in the background. These variations may be the result of the solar motion along the sky and/or of variations in the solar illumination of the natural environment.

3.2.1 Solar Motion

The daily solar motion across the sky causes the irradiation to change as a function of time (Figure 12). Therefore, the apparent background differs in the morning compared to the evening, because of the gradual change in the orientation of shadows and because of the angular reflection properties of the various background elements. These changes are slow in comparison to the proposed observation period in the order of a minute or so. However, if comparisons are made between scans which are ten minutes apart or more, than the differences in apparent sizes of shadows etc. may introduce false alarms. To minimise the problems related to the solar motion is to extend the detection algorithm to analyse more than two sequential scans simultaneously.

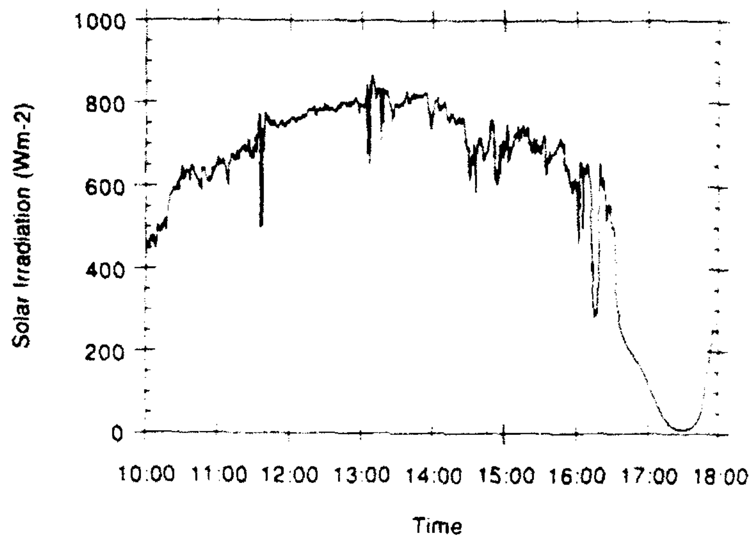

Figure 12. Solar irradiation as a function of time of the day. Considerable variations in the solar irradiation can occur on small and large time scales. Measurement were ended when a thunderstorm blocked the solar radiation of 17^{h}20.

If series of more than two scans are processed, a temporal evolution of the spectral content of each pixel in the image can be determined. Based on the temporal analysis of more than two sequential scans, a better prediction can be made of the expected spectrum in the next scan. The prediction can be used to be compared with the actual measured scan. Using the temporal analysis of the scans, a more reliable detection algorithm can be established. This algorithm will be implemented in a simplified manner in software to analyse the scans.

3.2.2 Cloud Cover Variations

The variations in the solar illumination occurs due to variations in the cloud cover. Usually, if there is some cloud cover, the clouds vary continuously while moving along the sky in the direction of the wind. If the wind velocities are of the order of 1 kilometre per minute and the scale size of the clouds are of the same order, variations in illumination are likely to be observed since the spatial resolution of the forest fire detection system will be of the order of 5 m at a range of 10 km. The whole cloud pattern influences the solar illumination at every location differently, which means that at every location the observed intensities varies. Hence, the reflected solar radiation at the vegetation and other background elements changes proportionally to the variations in solar irradiation, independent of the specific reflectivity's of the various background elements. The amplitudes of the variations depend on the type of cloud cover and the atmospheric conditions (i.e. transmission). At greater distances the amplitudes will be reduced with respect to those detected at shorter range as a result of atmospheric attenuation.

These variations in the illumination of the background due to a non-uniform cloud cover may result in significant differences when two images of subsequent scans are compared. In order to be able to identify the detection's which result from the variations in the solar illumination of the background, the system must be designed such that the apparent solar illumination at every location can be measured.

The solution to this problem is found in measuring at least two different spectral bands simultaneously. When the solar illumination varies, the reflected radiation will vary proportionally in the three bands. Hence, as long as the ratio of the measured intensities in the two (or more) bands does not vary, than no differences resulting from variations in solar illumination will be detected at all.

However, care should be taken not to eliminate the sensitivity in detecting forest fires, since the proposed method will also reduce changes induced by smoke in the background. This drawback is minimised by carefully selecting the wavelength bands by making use of the differences in spectral characteristics of the vegetation background and the smoke. As has been shown in Chapter 3.2 (Figure 5), the spectral characteristic of vegetation is markedly different from wildfire smoke. Therefore, by selecting three wavelength bands at 750 nm, 650 nm and 550 nm the detection probability of changes in the 3-point spectrum, when a smoke cloud erupts between two subsequent images, are optimised. Hence, by monitoring changes in the 3-point spectrum the wildfire smoke detection is almost independent of variations in the solar illumination due to a non-uniform cloud cover.

In principle, however, small variations in the solar illumination spectrum do occur when the cloud cover varies, since the spectrum of the sky irradiation consists of contributions from the sun, which has approximately a blackbody spectrum of 5800 K (yellow) and the rest of the sky, which is either blue, grey, or blue interspersed with grey clouds. Hence, when the sun is to be blocked by a cloud, the spectral characteristic of the illumination changes because the contribution of the yellow spectrum of the sun decreases. This spectral difference induces a varying illumination spectrum when the illumination changes by the non-uniform cloud cover. The effect is largest for cumulus clouds against a blue sky. However, the effect reduces when wildfires are to be discovered at long ranges because of the reduced contrasts due to atmospheric extinction.

3.2.3 Variations in Atmospheric Extinction

During the course of the day the atmospheric conditions change, which results among others in a varying atmospheric extinction. The varying extinction introduce changes in the apparent spectrum of background elements. If the transmission of the atmosphere decreases, the contrasts at all wavelengths decrease and hence the detection probabilities reduces. However, in general the variations in atmospheric extinction do not change rapidly and hence, over periods of the order of one minute, the chances for false alarms as a result of a change in atmospheric extinction are low.

3.2.4 Waving trees

Due to the influence of wind on trees and their leaves the position of these in the image of the natural environment will move with respect to the background (Figure 13). If a direct comparison is made between two scans which are recorded one minute apart, then many differences will be seen as result of the motion of leafs and trees in the foreground of the image. These cause many false alarms, which are difficult to eliminate if the system is not designed to cope with these problems.

We propose to minimise the false alarm rate due to this effect by confining our interest to detecting objects with a minimum size of 2 meters. This means in practice that in the implementation of the detection algorithm the image pixels of the foreground will be averaged to form square or rectangular blocks which have an apparent size of approximately two meters in the image. Figure 13 shows the principle of operation of the algorithm. At the bottom of the image the block sizes are largest (which represents the shortest ranges), while the block size decreases linearly toward the horizon as a result of the perspective. Above the horizon the procedure is reversed.

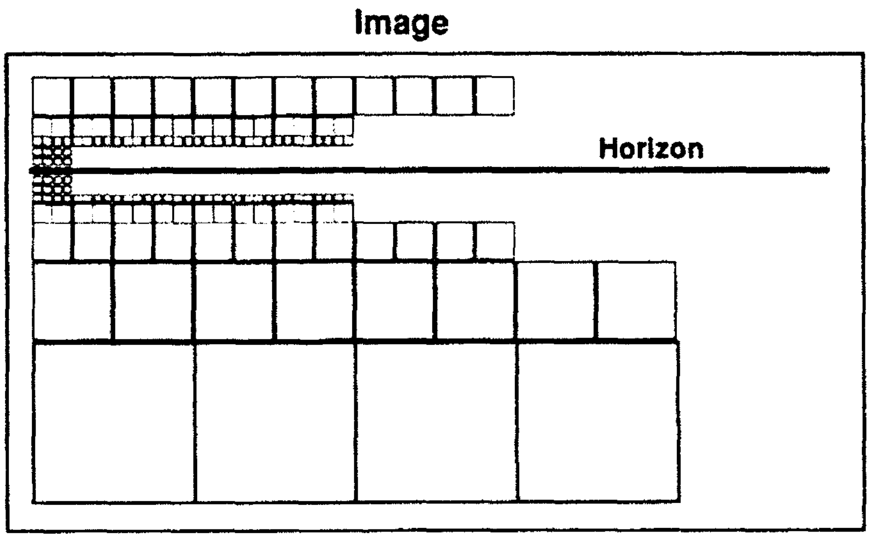

Figure 13. Schematic presentation of grouping of pixels into square blocks. The size of the block depends on the required minimum resolvable absolute size in the field, which depends on the opyics and pixel sizes in the detector array. The detection algorithm is caaried out for each block individually.

This (first) method of grouping pixels in the foreground to objects of an apparent size of approximately 2 meters, has the additional advantage that the processing load of the image processor is approximately halved with respect to the original situation. The amount of reduction of the processor load depends on the particular situation, such as height of the sensor above the forest, the type of background, etc.. An additional advantage of the proposed procedure is that the sensitivity to wildfires, which occur at close range, will increase, since the smoke of wildfires at close range will have a much larger angular dimension in the image than at large distances.
The proposed method generally works well in a relative flat environment. In a mountainous area a similar method may be applied, however, than for each sensor a different blocking scheme should be implemented depending on the particular environment of that sensor. For the demonstration in the Netherlands (July 1, 1993), this algorithm will be implemented. However, for the location which has been selected for the demonstration of the system in the Parnis area near Athens in Greece (Sept./Oct. '93), the whole area is approximately at the same distance of 10 km. Hence, for

this particular application no grouping of pixels will be applied.
The second method of discriminating moving leaves and trees is making use of the spectral information in the image. If the spectrum of a pixel resembles that of vegetation, than any temporal variation in the observed intensity as a result of the motion of trees in the wind may be ignored.

3.2.5 Human caused False Alarms

Many alarms may have a human origin, such as smoke clouds from industrial origin and agricultural activities, dust clouds from vehicles on dirt roads, vehicles etc., and should therefore not be interpreted as wildfires. For this reason, provisions should be designed to discriminate human caused alarms from wildfires.

Industrial and agricultural activities often produce smoke. The smoke alarms from these activities should be primarily discriminated on the basis of their locations in the area. Since locations in the area are in general determined by the central co-ordination computer, which analyses the directional information of alarms detected by all sensors, the cross-correlation with the database on areas excluded from surveillance should be performed in that system. This flow chart of analysis assumes that the area under surveillance is relatively flat. In the case of mountainous areas, the image processing computer near the sensor is able to determine the location of an alarm before sending the information to the central co-ordination computer, since the determined direction of an alarm translates directly into a location using geographical information.

Dust clouds. In the case of alarms from dust clouds, caused by vehicles driving on dirt roads, a similar technique may be applied as for smoke from other human activities. That is identification of human caused dust clouds on the basis of their location near dirt roads.

A second way of discriminating a dust cloud from smoke is to evaluate the temporal behaviour of the cloud. Since dust aerosols are generally larger in size and therefore heavier than smoke aerosols, the dust cloud 'rains out' much quicker than smoke clouds. This temporal information may also be used when the discrimination of dust clouds from smoke clouds is a problem.

A third way of identifying the alarm form dust clouds as false, is to use the available colour information. In general, the colour of a dust cloud differs from smoke because of a different chemical composition and a larger size distribution for the dust aerosols. Depending on the type of soil, the dust cloud may appear lighter or darker than the smoke cloud and may also have a different colour. If this is the case, than also a discrimination on the basis of colour becomes possible.

Cars and other moving objects resulting in alarms from human activities should be solved similarly as dust clouds by means of discrimination on the basis of their location, and temporal and spectral characteristics. Since these objects generally move fast with respect to the scanning period of the sensor (≈ 1 min.) or don't move at all, these objects should be easily identified by the system. Another characteristic that may be used by the detection algorithm is that shape of these objects does not change with time, and the size only gradually.

Very similar to the problem of moving object is related to false alarms that may be caused by animals, such as birds passing through the field of view of the sensor. Since these occurrences cannot be associated with any location or spectral characteristics, these can only be analysed on the bases of temporal behaviour.

3.2.6 Missed Detection's

A problem associated to optimising the detection and false alarm rates is determining the detection threshold for wildfires. In principle, any surveillance system may be designed such that the false alarm rate will be approximately zero, however, many occurring wildfires will not be detected because of the high detection threshold.

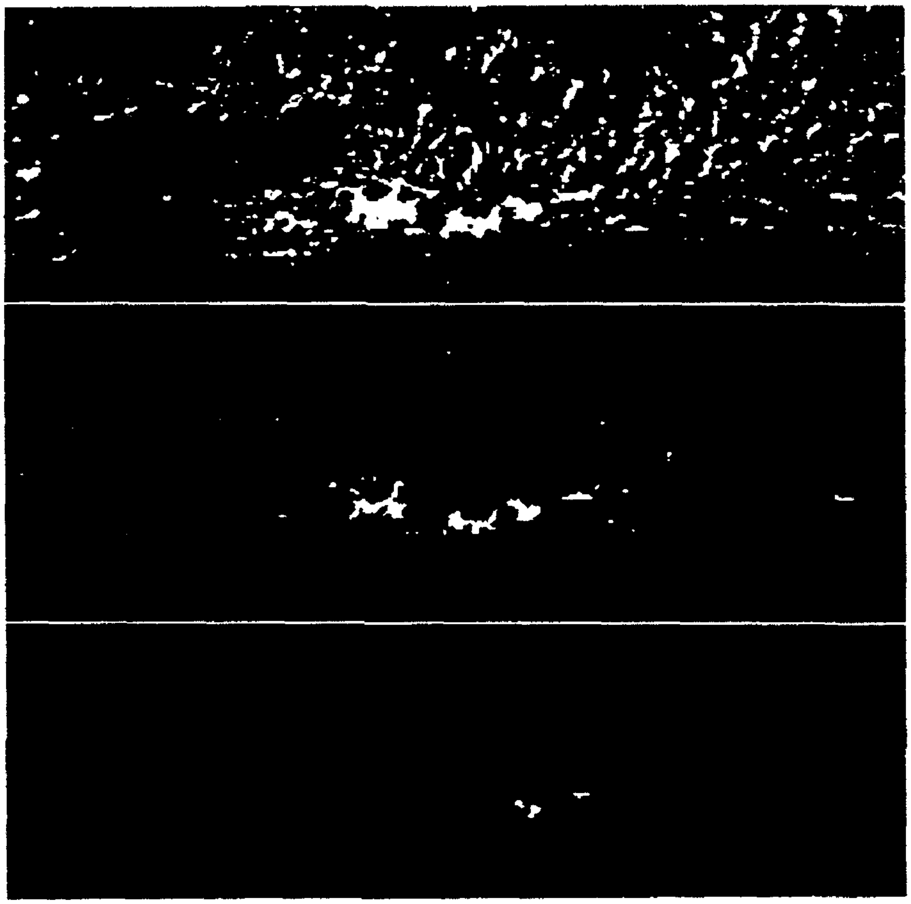

Figure 14. False alarms as a function of the wildfire detection threshold. The binary images are obtained by subtracting a background from the image shown in Figure 7. The detection threshold is highest in the top image, and is gradually decreased for the two lower images. False alarms are mainly caused by the motion of trees in the wind.

On the other hand, if the detection threshold is very low, than most wildfire will be detected at the cost of many false alarms. The problem here is optimising the relationship between the false alarm rate and the detection or hit rate of the surveillance system. The relationship between the system response and the state of nature is schematically shown in Figure 15, while the statistical relation between detection rate and false alarm rate is graphically shown in Figure 16. Therefore, experiments need to be conducted to test the false alarm rate of the sensor with the number of missed alarms using the Receiver Operating Characteristics (ROC) methods [13]. This method enables the optimum determination of minimum false alarm rates versus maximum correct detection's (hits).

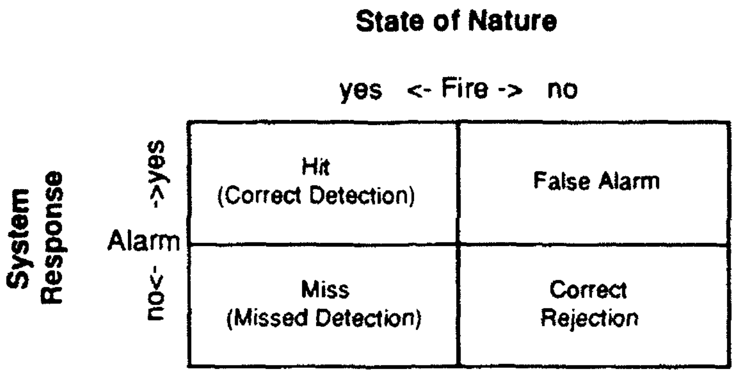

Figure 15. Schematic relationship between the State of Nature and the Wildfire Detection System response. Both parameters only have yes and no as values.

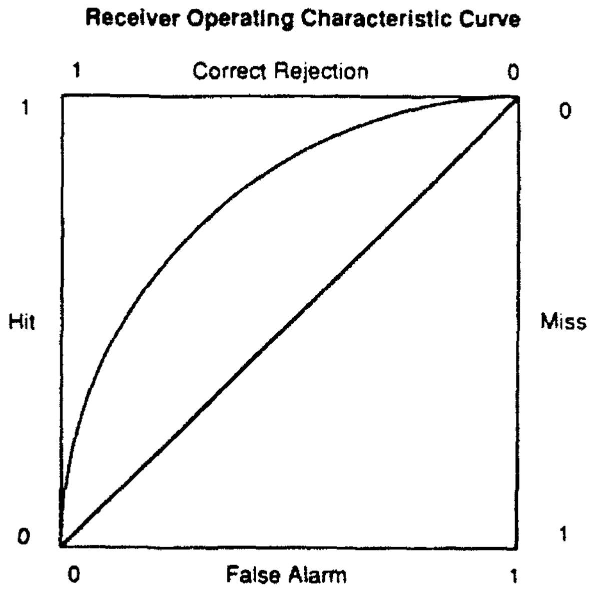

Figure 16. Receiver Operating Characteristics Curve (ROC) for two independent binary variables (i.e. as described in Figure 15), which have yes or no as values. The vertical axis represents the hit rate of the surveillance sensor and the horizontal axis the false alarm rate. The diagonal represents the relation for random answers as a function of the detection threshold. The curved function represents the statistics of an arbitrary surveillance sensor. The sensor is optimised when both the hit rate and correct rejection rate are maximised. For the ideal sensor both are near 1.

3.3 Sensor Design and Implementation

The basic autonomous wildfire detection demonstration system will consist of a (i) sensor, (ii) a controller and (iii) a data-analysis computer for image processing, communication and data presentation. In what follows, a short description will be given of the system design and implementation.

The sensor will consist of a platform with three camera's, each operating a linear CCD detector array. In front of each camera a filter with 60 nm band passes centred on 550 nm, 650 nm and 750 nm resp. has been placed to provide the sensor with colour information. Each linear CCD detector array consists of 512 detector elements, each detector is 13x13 m in size (w x h). Since the focal length of the lens equals 50 mm, the IFOV of a detector equals approximately 2.6 x 10^{-4} sr^{-1}. The vertical FOV therefore corresponds to 7.6 °. The read-out of the detector arrays is operated at a clock frequency of 10 MHz. The integration time of the detectors are programmable, depending on the light intensity levels. The dynamic range of the pixel data equals 12 bit. The sensor will be mounted on a rotating platform, such that the orientation of the linear CCD is vertical. By synchronising the rotation of the sensor with the read-out frequency of the CCD an image can be formed of the natural environment.

The demonstration sensor operates three separate linear CCD camera's to provide the sensor with the colour information, however, recently, an linear CCD RGB-colour camera has been developed, which may be customised optimising the colours for wildfire surveillance and detection. Discussions with the manufacturer concerning customisation have started.

The programmable controller consists of (i) three 4 MHz 12-bit A/D conversion units, (ii) three separate banks of 512 offset and gain correction units to correct each detector element for individual offset and gain variations in real time. The last section of the controller is designed to organise the data into groups or blocks of pixels before transferring the data to the data-analysing PC. The controller is easily reprogrammed for operation in different environments, such as a flat country in the Netherlands, as well as for the mountainous area of Parnis near Athens in Greece. The various settings of parameters in the controller can be changed by means of a simple TTY terminal.

The sensor and its controller will be powered by a photo voltaic unit provided by the University of Patras.

The PC receives the 12-bit data from the controller into a 12-bit data-acquisition board (Imaging Technology Inc.), which is used to temporarily store, organise and present the data. In addition, each colour image will be written to a 1 GByte disk. Then, the data will be processed to detect forest fires using the colour and temporal information. Before presentation to the screen, the data will be compared with available information in the database on the data relevant to that particular location. The final results of the computations will be overlaid on top of the presented image and, in addition, will be relayed to the expert system / database. Wireless data communication with the central database / expert system will be provided by the University of Patras (Greece).
The performance of the sensor and data-acquisition and -analysis is determined by the frequency with which the sensor will scan the horizon. The performance of the total system depends on the

(i) CPU of the computer (50 MHz 80486 DX);
(ii) analog-to-digital (A/D) conversion frequency (4 MHz);
(iii) storage capacity (32 MB RAM);
(iv) algorithm;
(v) number of pixels in the recorded image (yyy * 512), yyy depending on demonstration;
(vi) number of colours per pixel (3), and
(vii) dynamic range per colour (12 bit), to be analysed.

The number of pixels on the background image is determined by the FOV of the sensor and the IFOV of a single detector. Hence, if the spatial resolution of the system is increased, than the number of pixels to be analysed will also grow (proportional tot the square of the spatial resolution) and, hence, the throughput of the sensor system will be reduced. Therefore, the total system performance will be a trade-off between the parameters listed above and, in addition, will depend on the local circumstances and system requirements during demonstration. These parameters will be set and determined during the tests of the demonstration sensor in the second quarter of 1993. The final demonstration of the autonomous wildfire surveillance and detection system will be carried out in July (1), 1993 in the Netherlands and in October, 1993 in the Parnis area in Greece.

4 CONCLUDING REMARKS

As for normal forest fire surveillance, autonomous forest fire surveillance is usually carried out from ground based lookouts and from aeroplanes. For the earliest detection of forest fires, airborne surveillance should use IR sensors for detection of hot spots on the ground, while ground based surveillance sensors should find smoke clouds in the visible and near-IR wavelength band (400 - 1000 nm).

The implementation of reliable autonomous forest fire surveillance systems is complicated by the variable natural environment in which forest fires have to be detected. The imagery of the environment acquired by surveillance sensors varies continuously with the illumination of the background due to time and changes in weather. such as the daily motion of the sun along the sky, seasonal variations in vegetation, and variability's in cloud cover, atmospheric transmission, wind, etc.. All these changes in the environment may be picked up by the surveillance system as false alarms. On the other hand, by decreasing the sensitivity to false alarms the detection sensitivity may decrease resulting in missed detections. Therefore, special care needs to be taken in the design of surveillance sensors and image processing software to optimise its reliability employing the available information present in the time and space domain, and the electro-magnetic spectrum. The reliability of the system can be further improved using GIS and historic data of the area in expert system environment.

REFERENCES

1. Smith, R.A., Jones, F.E. and Chasmar, R.P., *The Detection and Measurement of Infrared Radiation*, Clarendon Press, Oxford, England 1968.

2. Wolfe, W.L., Zissis, G.J., *The Infrared Handbook*, Office of Naval Research, Department of the Navy, Arlington, VA, 1978.

3. Deepak, A., *Atmospheric Aerosols: Their formation, optical properties and effects*, Spectrum Press, Hampton, VA, 1982.

4. Chandrasekhar, S., *Radiative Transfer*, Dover Publications Inc., New York, 1960.

5. Kneizys, F.X. Shettle, E.P., Anderson, G.P., Abreu, L.W., Chetwynd, J.H., Selby, J.E.A., Clough, S.A., Gallery, W.O., *Atmospheric Transmittance/Radiance Computer Code Lowtran 7*, AFGL-TR-88-0177, AFGL, Ma., 1988.

6. Jacobs, P.A.M., *IR Characterization of Targets and Backgrounds*, SPIE Orlando April '92, SC29, 1992.

7. Fantechi, R., Maracchi, G., Almeida-Teixeira, M.E., *Climatic change and impacts: A general introduction*, Report EUR 11943 EN, Commission of the European Community, 1991.

8. Brown, A.A., Davis, K.P., *Forest Fire, Control and Use*, p. 327, McGraw-Hill Book Company, New York, 1973.

9. Chandler, C., Cheney, P., Thomas, P., Trabaud, L., Williams, D., *FIRE IN FORESTRY (Vol. II): Forest Fire Management and Organization*, p.69, John Wiley & Sons, New York, 1983.

10. Stearns, J.R., Zahniser, M.S., Kolb, C.E. Sandford, B.P., *Airborne infrared observations and analysis of a large forest fire*, Applied Optics, Vol. 25, No. 15, p. 2554, 1986.

11. Kourtz, P., *The Need for Improved Forest Fire Detection*, The Forestry Chronicle, p. 272, August 1987.

12. Garifo, L., *Fire Prevention and Fighting go High-tech in Italy*, Laser Focus World European Electro-Optics, Winter, 1991.

13. Swetz, J.A., Enhancing Human Performance: Issues, Theories & Techniques, Natl. Acad. Pr., 1988.

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THIS WORK HAS BEEN CARRIED OUT IN A PROJECT (NR. 0040) IN THE FRAMEWORK OF THE EPOCH PROGRAMME OF DIRECTORATE-GENERAL XII OF THE COMMISSION OF THE EUROPEAN COMMUNITIES IN BRUSSELS, AND FOR BOSSCHAP IN THE HAGUE.

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